Can WEPP estimate BMP effectiveness from experimental forest roads?

VirginiaTech

Kris Brown and
Kevin McGuire, Cully Hession, Mike Aust

Virginia WATER RESOURCES Research Center

Forest Resources & Environmental Conservation at Virginia Tech

VIRGINIA DEPARTMENT OF FORESTRY

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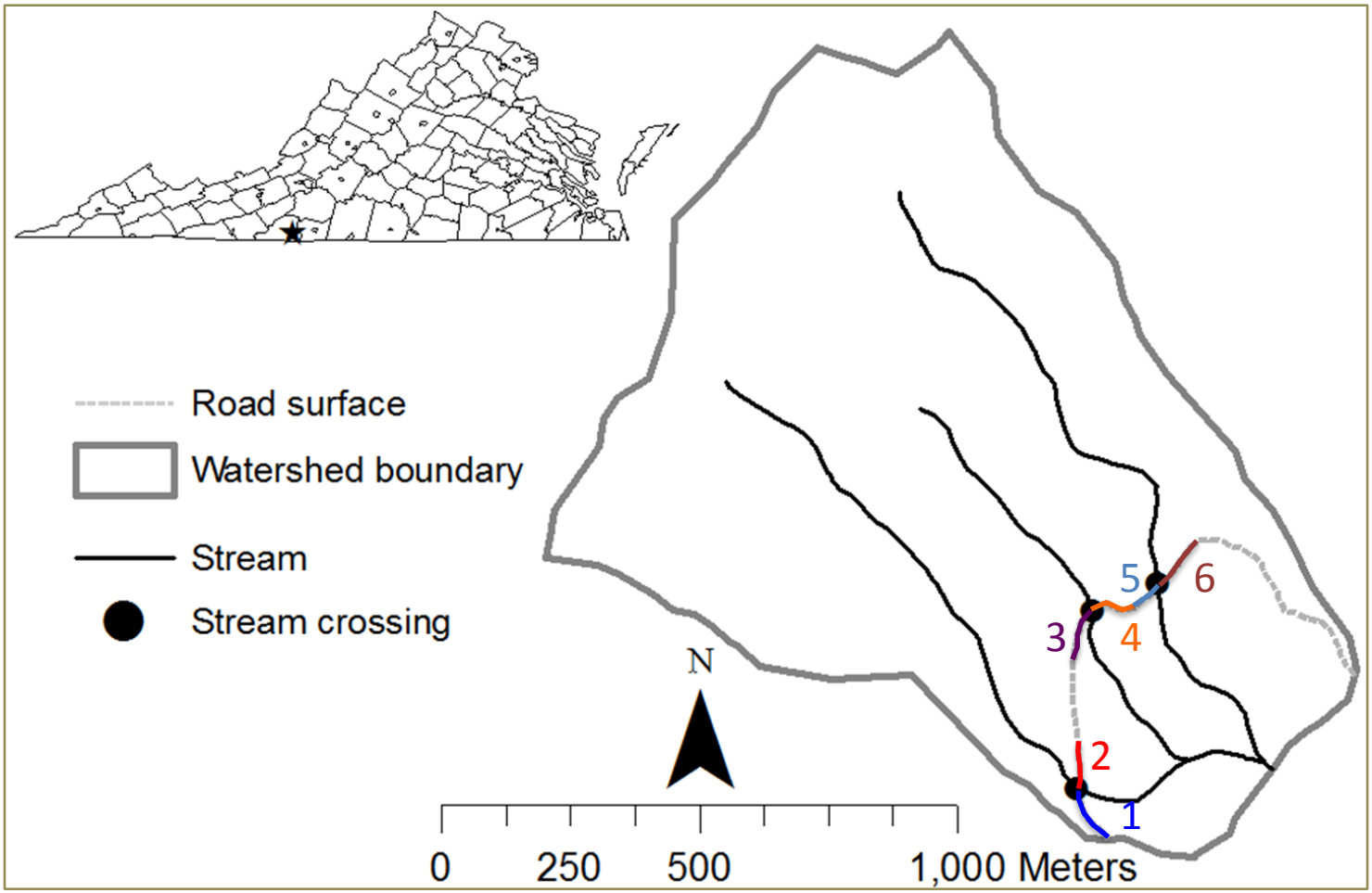
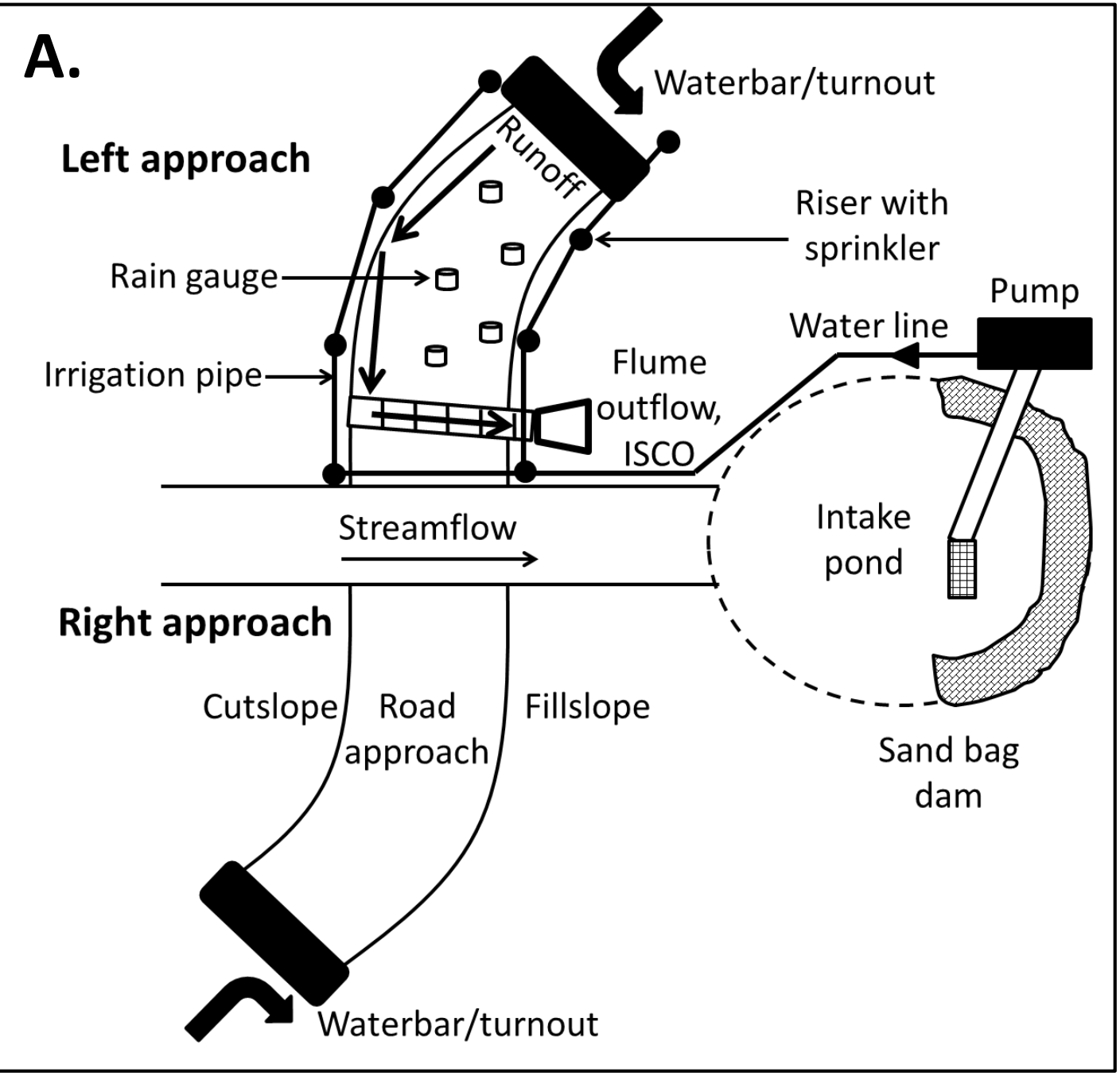
Need to document the efficacy of BMPs to reduce sediment delivery from roads… **How?**

- Monitoring programs are typically too costly and time prohibitive. Can't visit all sites.
- Experiments are site specific and costly
- Models are often touted as a solution and good for what if scenarios
  - Empirical, e.g., USLE
  - Process-based, e.g., WEPP, KINEROS2

Rainfall simulation study




A.
Waterbar/turnout
Runoff
Left approach
Riser with sprinkler
Rain gauge
Pump
Water line
Irrigation pipe
Flume outflow, ISCO
Streamflow
Intake pond
Right approach
Cutslope
Road approach
Fillslope
Sand bag dam
Waterbar/turnout


B.


C.
AUTOCRAFT
MARINE

Different intensities of BMPs (graveling) on the road approach to stream crossings.

No gravel

10-19% cover

Low gravel

34-60% cover

High gravel

50-99% cover

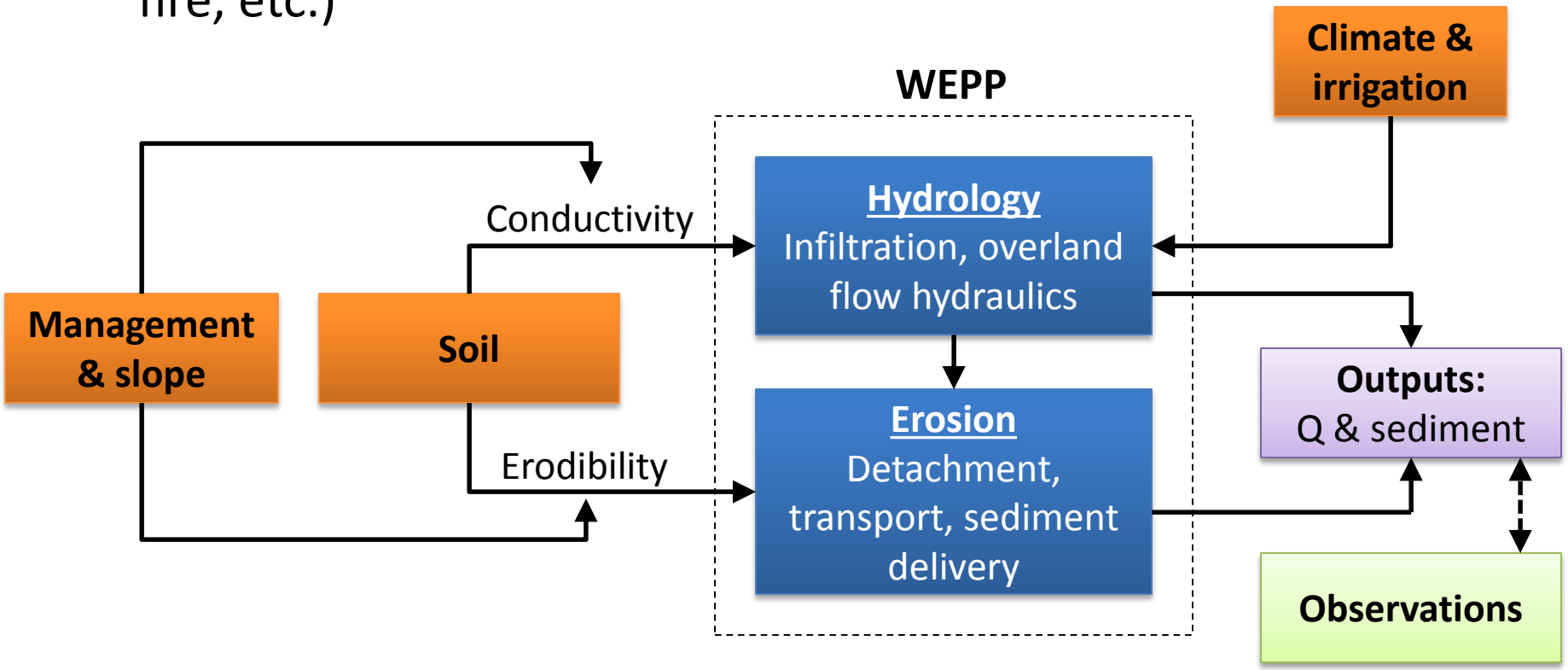
Objectives

- Calibrate WEPP with a evolution-based optimization approach to explore
  - parameter identifiability
  - parameter sensitivity
  - prediction uncertainty

- Determine overall prediction performance of WEPP and its ability to distinguish between different BMP intensities

What is the Water Erosion Prediction Project (WEPP)?

- It's a process-based erosion model developed by the USDA as replacement for USLE.
- Forest Service has provided guidance for forest use (roads, fire, etc.)

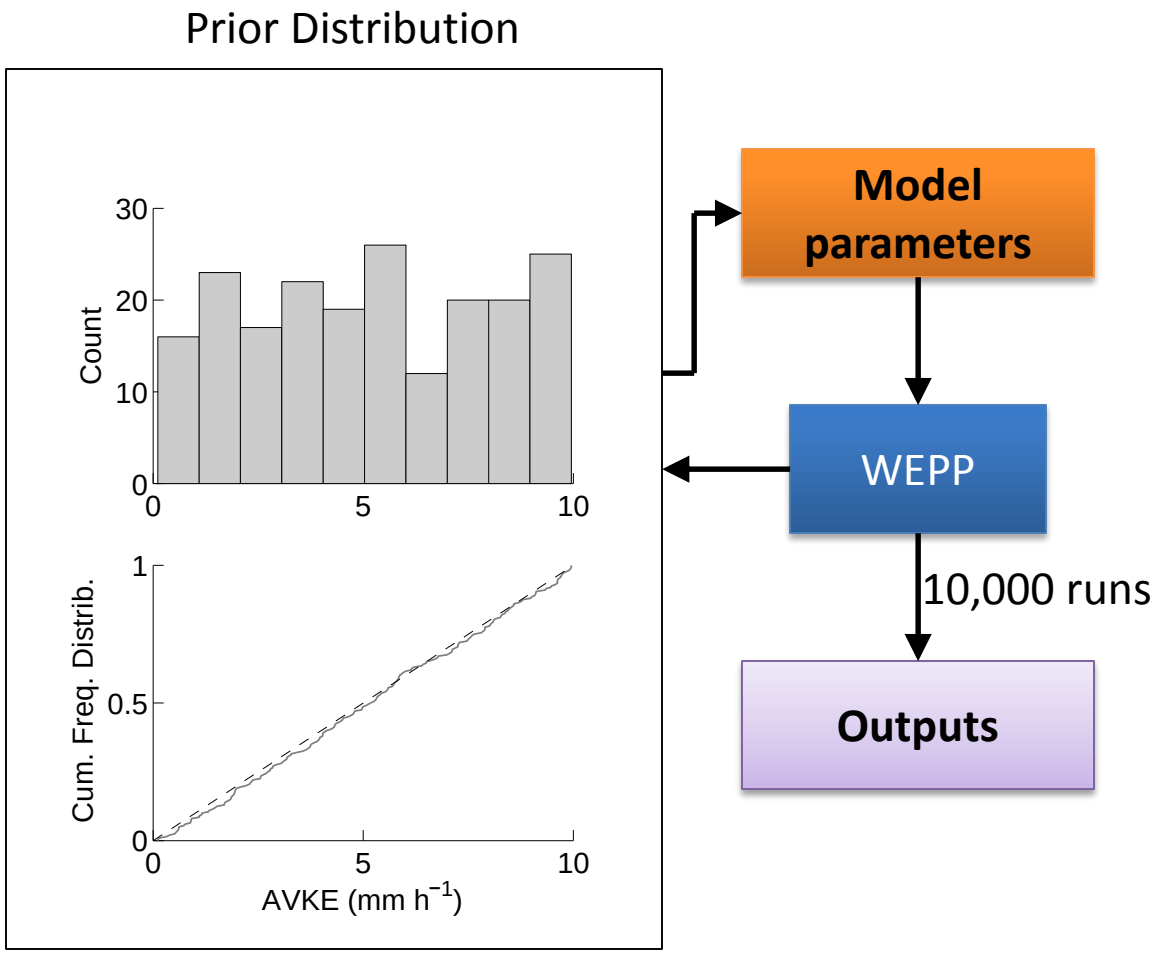


Model setup

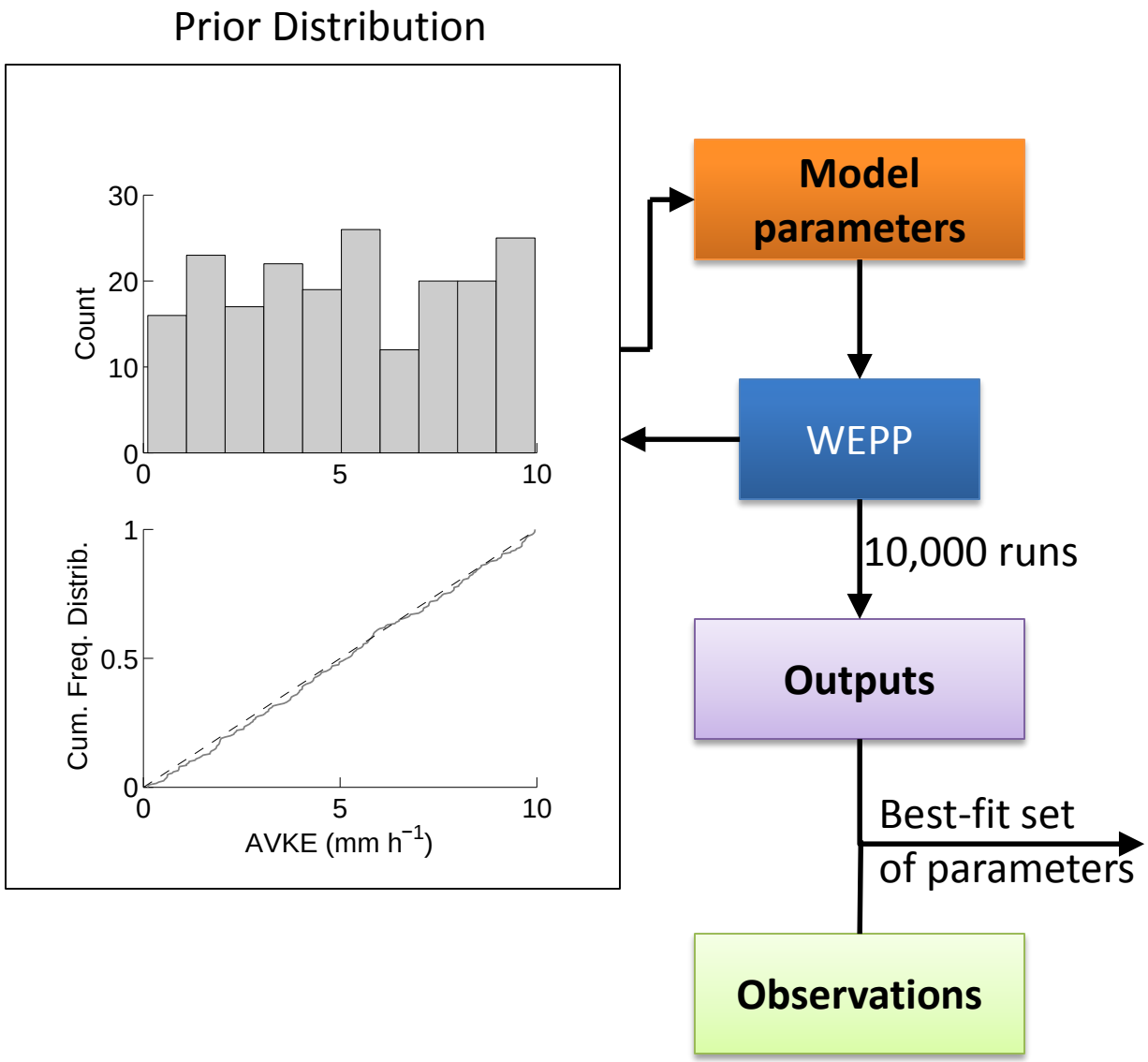
- Unique hillslope profiles for each rainfall simulation experiment.
- Uniform distributions of input parameters related to runoff and sediment yield

Parameter	Description	Units	Min	Max	WEPP file
RRINIT	initial ridge roughness after last tillage	m	0	0.08	Management
WIDTH	initial rill width	m	0	0.2	Management
K_i	baseline interrill erodibility	kg s m^{-4}	$2x10^6$	$11x10^6$	Soil
K_r	baseline rill erodibility	s m^{-1}	0.0001	0.01	Soil
SHCRIT	baseline critical shear	N m^{-2}	0.84	3.84	Soil
AVKE	effective hydraulic conductivity	mm h^{-1}	0.5	10	Soil

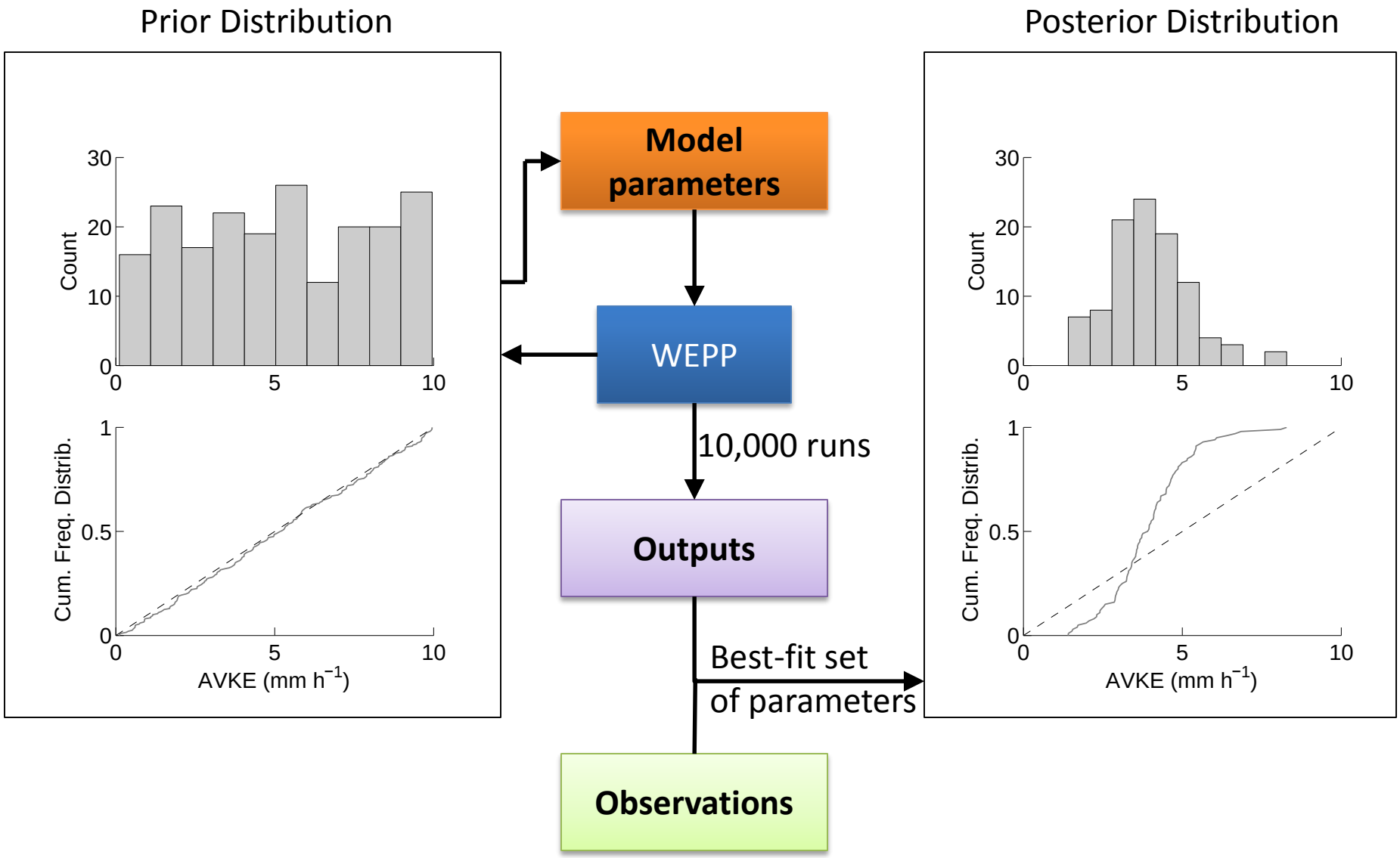
Parameter identifiability & sensitivity



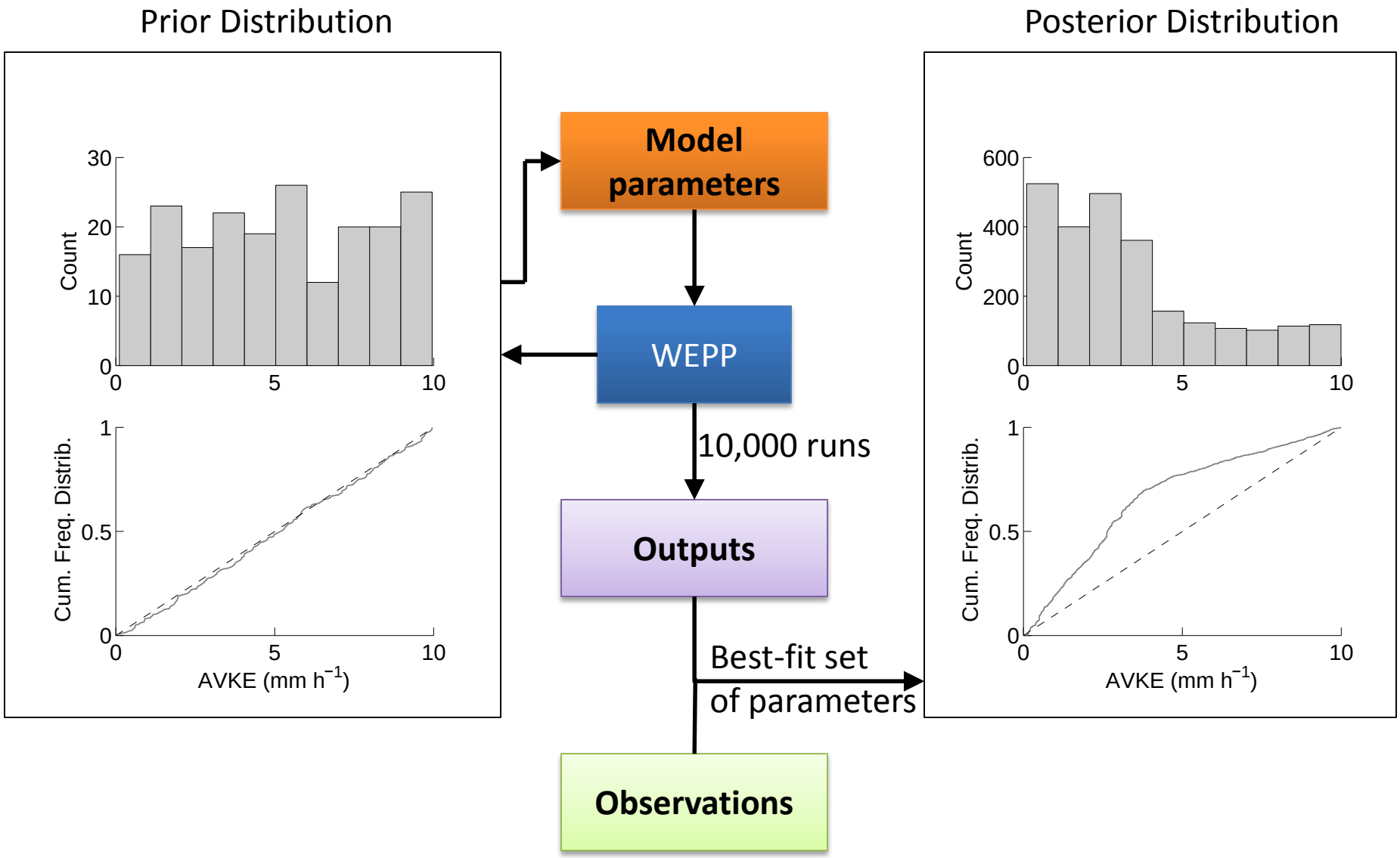
Parameter identifiability & sensitivity



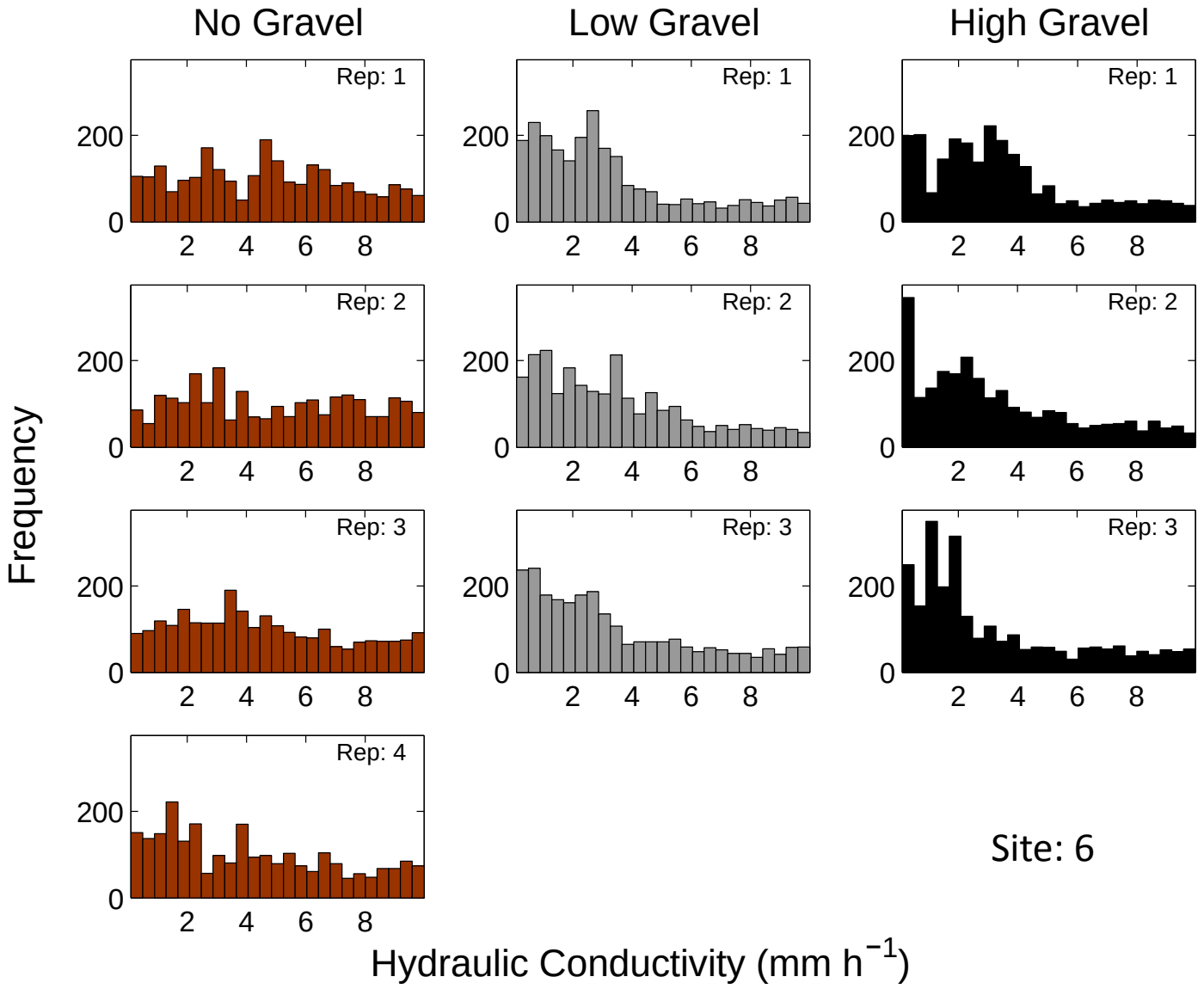
Parameter identifiability & sensitivity



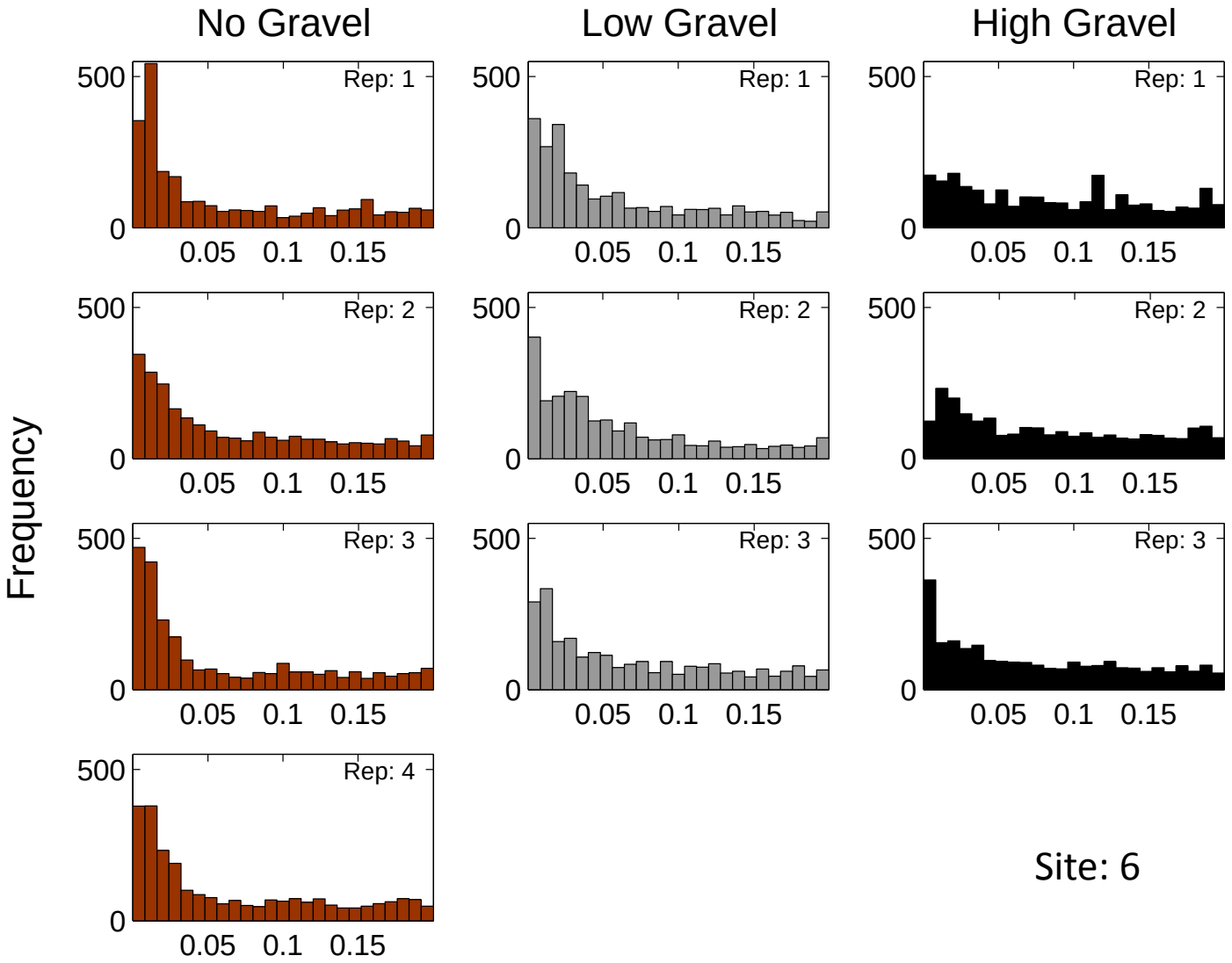
Parameter identifiability & sensitivity



Hydraulic Conductivity Posterior Distributions

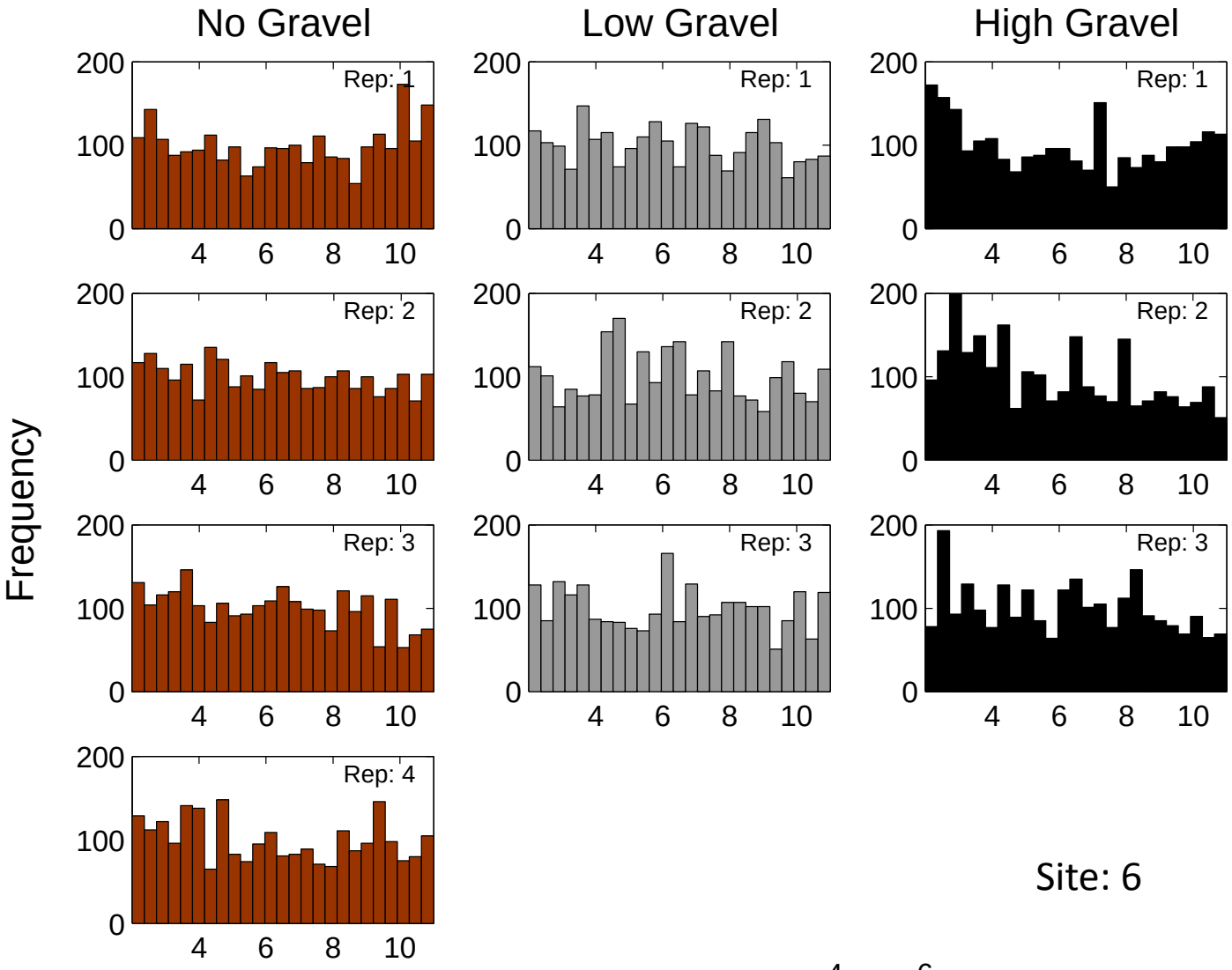


Rill Width Posterior Distributions

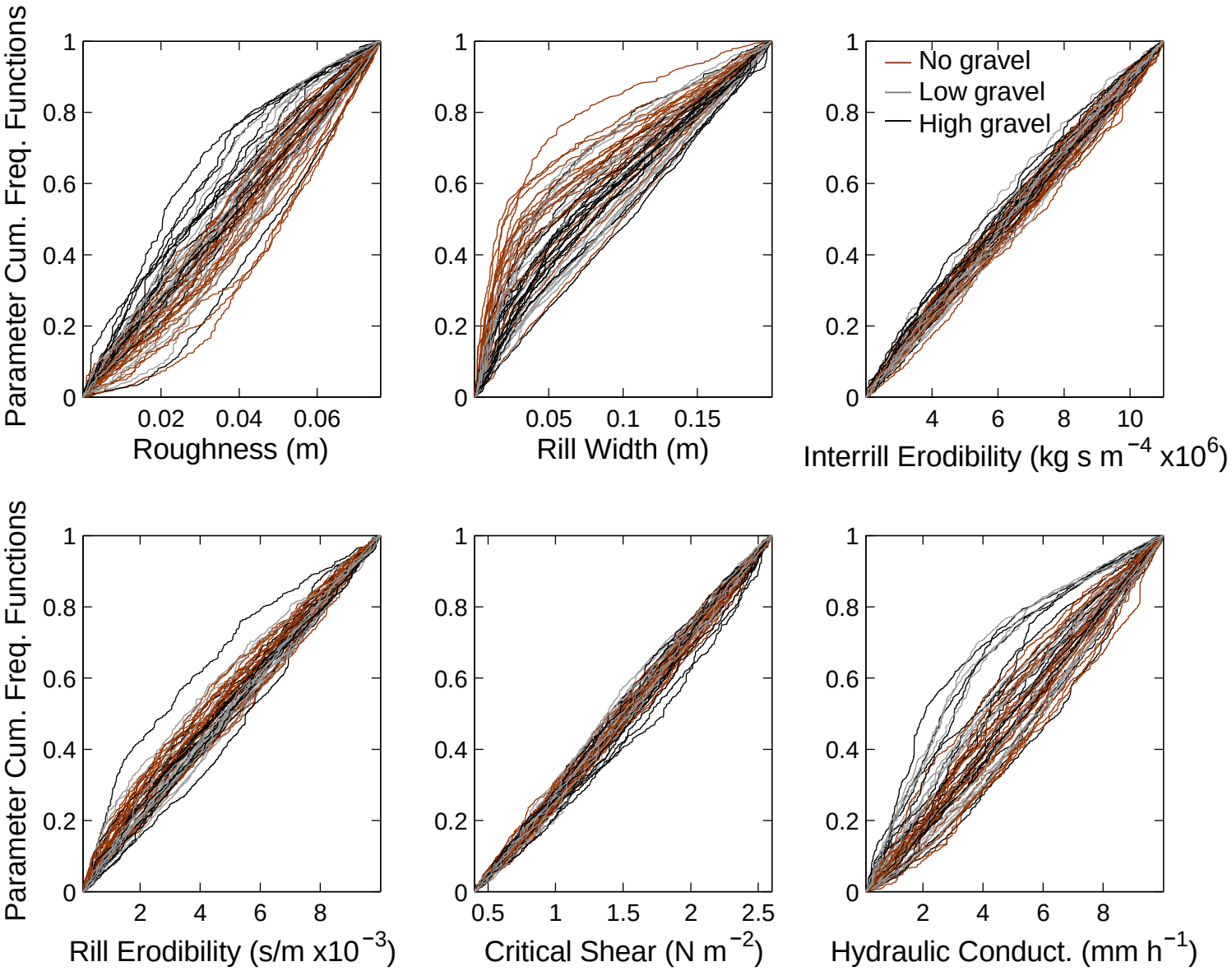


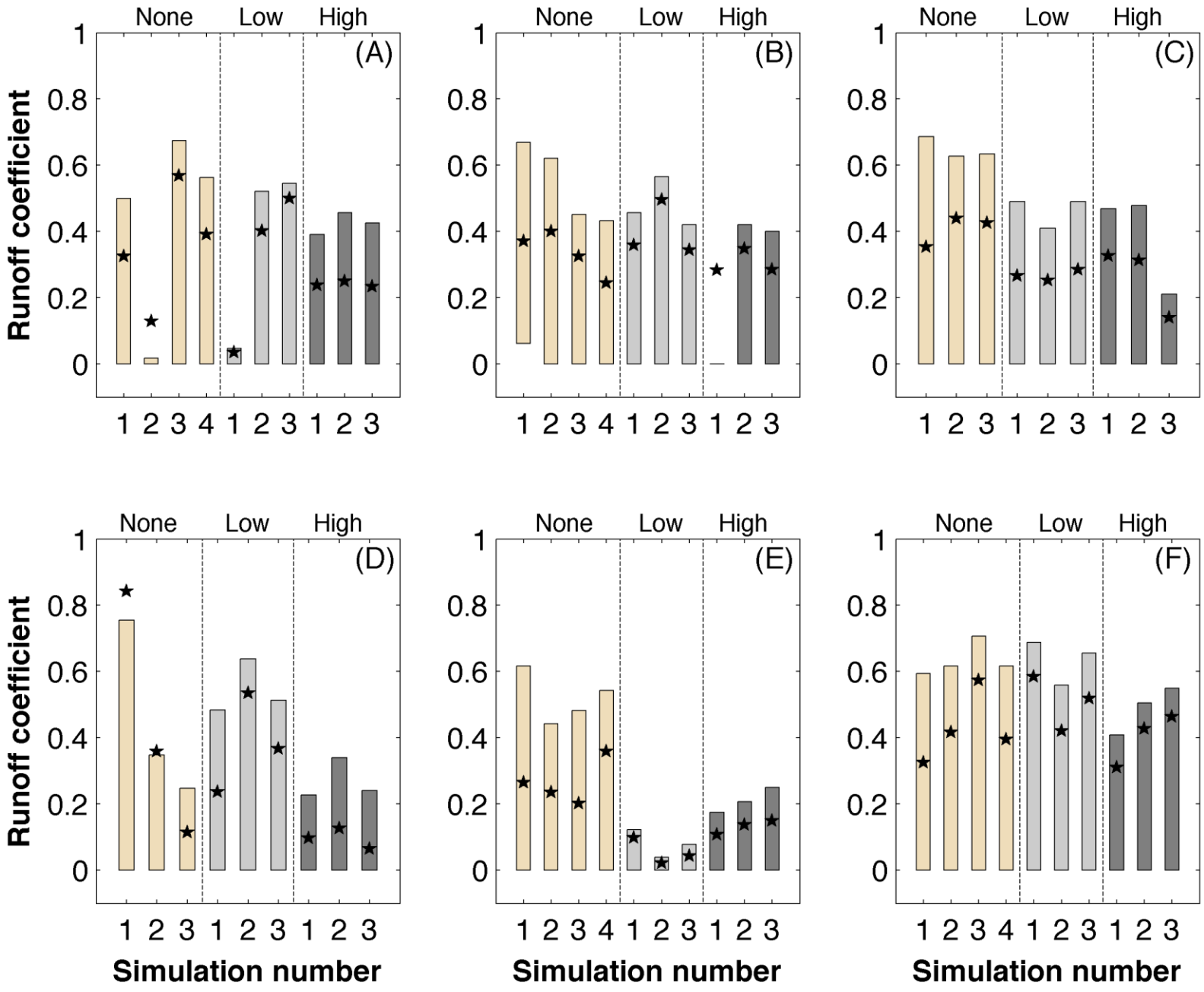
Site: 6

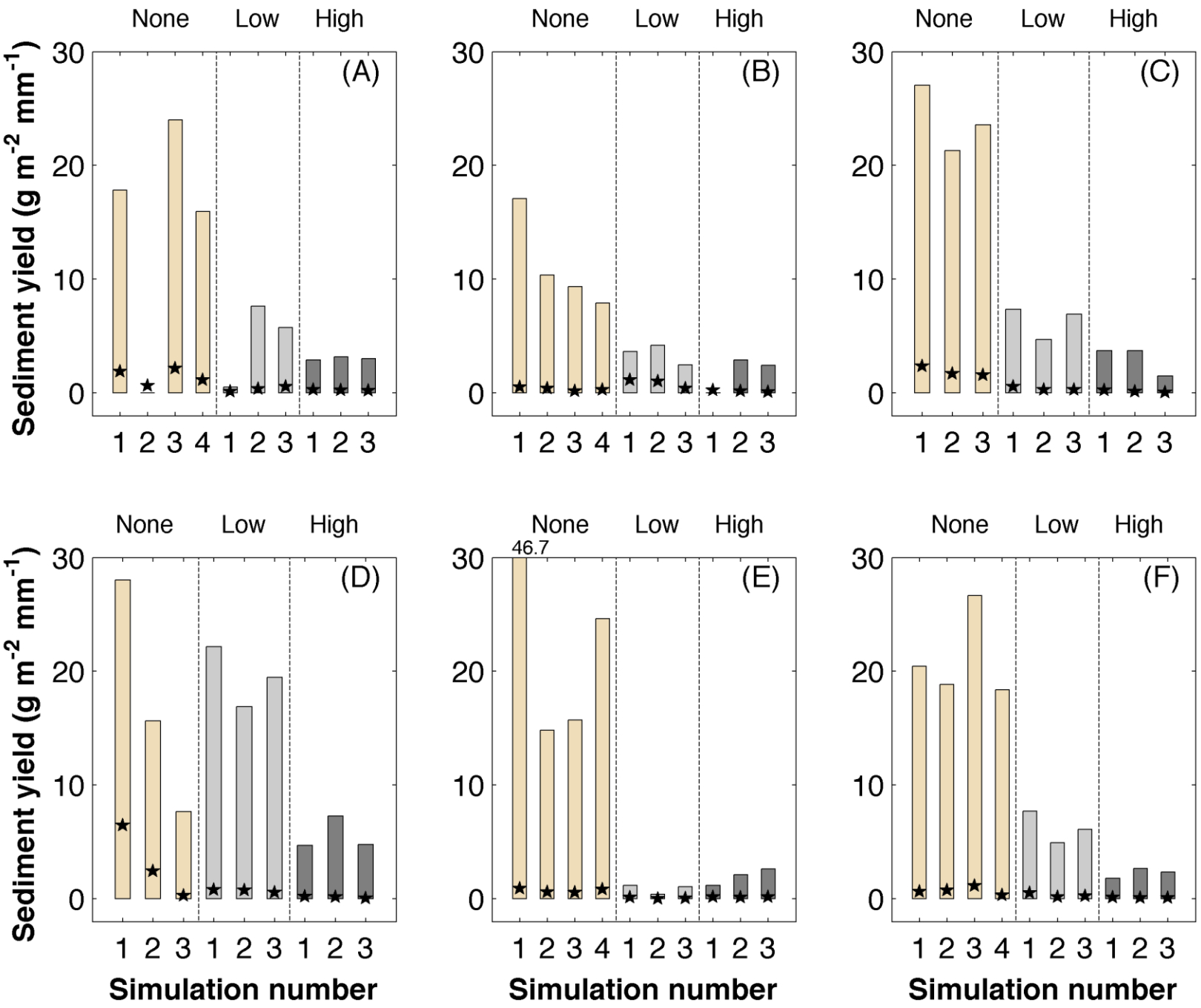
Interrill Erodibility Posterior Distributions



Complete set of posterior distributions for all sites, all reps: 58 rainfall simulations




None
Low
High
(A)
(B)
(C)
(D)
(E)
(F)
Runoff coefficient
Simulation number
0
0.2
0.4
0.6
0.8
1
1 2 3 4 1 2 3 1 2 3


None
Low
High
(A)
(B)
(C)
(D)
(E)
(F)
46.7
Sediment yield (g m-2 mm-1)
Simulation number
0
10
20
30
1 2 3 4 1 2 3 1 2 3

WEPP evaluation conclusions

- While prediction uncertainty was large, runoff patterns were generally captured.
- Sediment yield predictions showed clear differences among road surface treatments.
- Little guidance available on reasonable parameter values and some parameters are not sensitive which leads to high uncertainty

Implications

- WEPP can be useful for estimating BMP effectiveness…
  - Predictions captured the ranking of BMP intensity (i.e., no gravel to high gravel)

- BUT prediction uncertainty is large and should be considered in management and planning.

- Sediment predictions from models should ALWAYS include uncertainty, e.g., 10.3 t/a/y (±2.3)

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Rainfall Simulation Descriptions

Site ID	Surface cover (%)			Mean rainfall duration (min)			Mean rainfall intensity (mm h^{-1})		
	No Gravel	Low Gravel	High Gravel	No Gravel	Low Gravel	High Gravel	No Gravel	Low Gravel	High Gravel
1	10	35	90	21	20	35	51	40	48
2	15	40	50	24	30	24	63	24	30
3	17	60	90	19	24	22	64	58	52
4	10	34	50	16	14	14	56	64	64
5	14	47	63	23	15	13	60	48	46
6	19	60	99	33	23	18	56	72	60

Rainfall Simulation Observed Runoff & Sediment Yield

Treatment	TSS load (kg)			Runoff (mm)			Rainfall (mm)			Runoff coefficient		
	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
No Gravel	0.29	1.73	6.41	0.7	7.4	16.6	5.6	20.2	42.0	0.11	0.36	0.84
Low Gravel	0.04	0.38	1.86	0.3	5.5	21.5	8.8	14.8	36.8	0.02	0.35	0.58
High Gravel	0.04	0.17	0.57	0.9	3.5	9.6	4.2	15.0	29.6	0.07	0.24	0.46

□